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Potential for car use reduction through a simulation approach: Paris and Lyon case studies

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Abstract

The aim of the present study is to evaluate the possible extent of modal shifts from car use to “alternative modes” (public transport, cycling, walking) without any change in individual patterns of activity. Our approach is based on a transfer procedure that allows us to simulate the maximal potential market for transport modes other than the private car.

The method is based on repeated iterations of a simulation model that assigns journeys to transport modes other than the automobile on the basis of a number of improved public transport scenarios. Demand is channelled towards individual modes (walking, cycling), public transport and a combination of individual and public modes, on the basis of their relative time and distance performance.

The modal transfer procedure is applied to several transport supply scenarios, which provide a picture of what is possible in the sphere of modal split. Each simulation entails a potential transfer of private vehicle kilometres to each of the other modes. Even where different public transport scenarios are simulated, the transfer is evaluated for rounds trips in both the Paris and Lyon surveys. There is therefore no modification in the activity pattern of the people surveyed nor trips induced by improvements in transport supply. The aim is not to predict what would be the modal split in other circumstances, but the upper limit of the shifts.

This paper presents our methodology and the principal results obtained through numerical simulations based on figures for the Paris and Lyon conurbations. This approach demonstrates that a policy focused on modal shifts has the potential to reduce car use, but that

this potential is limited. Any aspiration to reduce car use further would mean changes in the patterns and location of activity.

Keywords

Individual daily mobility; modal transfer; modal split simulation method.

1. Introduction

Over the last thirty years, transport policy, especially in France, has been oriented towards the development of radial and suburban motorways and new rail services (metro, Express Regional Railways and light rail). The focus of transport policy has been more speed. It is now recognised that this policy has contributed to a gradual sprawl in urban populations and job distribution.

As a matter of fact, the enhancement in individual mobility through faster and cheaper travel has contributed to the spread of population from the centres and dramatic changes in individual modes of transport. There have been significant reductions in walking and cycling, substantial growth in car use, and a slight modification in the use of public transport. The car now dominates the other modes of transport in the Paris metropolitan area (see table 1). This increase in the car's share, combined with urban expansion and the "peripheralisation" of traffic flows, brought about a 35% increase in average journey speed in urban areas in France between 1982 and 1994 (Orfeuill, 2000).

Table 1: Percentage of all trips made by car in French urban areas in 1994

Car's share/all transport modes	French urban areas with more than 300,000 inhabitants (excluding Paris)	Paris urban region
Trips	62%	47%
Kilometres	83%	62%
Change 1982-1994 (trips)	+ 10 %	+ 8 %

Source: National Transport Surveys – 1982 and 1994 (INSEE-INRETS)

As a consequence of these significant changes, a majority of public opinion favours a reduction in car dependence and increased reliance on walking, cycling and public transport. There is some evidence, therefore, that the shift to car dependence is not in line with public opinion. Legislation (on air quality, urban regeneration, etc.) and national policy orientations ("Plans de Déplacements Urbains" (PDU) – urban travel plans) seek to reflect these expectations.

However, even when local political support is strong, the targets for car traffic reduction seem very low (around 2-3%). Such apparent lack of ambition is consistent with the results of different modelling approaches. For example, in aggregate long-term forecast models (Bresson G. *et al.*, 2002.), the estimates for the cross elasticity of car traffic to public transport supply are low, as is the direct elasticity of car traffic to fuel prices: income remains the major factor driving the growth in car use. Sensitivity to other parameters may be tested in disaggregated, short-term approaches, such as those developed at RATP with "Impact 3" (A hierarchical logit model – RATP, 1999). Again, elasticities are quite low. The direct elasticity of public transport patronage to vehicle travel times and waiting times is in the range of 0.1-0.2, and the impact of reduced parking supply on car traffic is purely local. These approaches have their own value and rationale. However, many commentators consider them too dependent on past or current behaviour (Papon *et al.*, 2000) and to have a "black-box" model structure.

In order to “open the black box” and evaluate the possible extent of modal shifts from car use to “alternative modes” (public transport, cycling, walking), we developed at INRETS a simulation approach with *explicit* rules.

The method is based on repeated iterations of a simulation model that assigns car trips to modes other than the automobile on the basis of a number of improved public transport scenarios. The method makes it possible to simulate the *maximum potential market* for transport modes other than the private car.

For each observed car “loop”, we construct the best solution using alternative modes. We then apply an explicit system of rules to decide whether this alternative is acceptable or not. The originality of the method lies in the modal transfer procedure that has been developed: car “loops” (or car round trips i.e. the sequence of all trips the individual makes between leaving and returning home), are assigned to one or other of the alternative modes on the basis of elimination rules (no walking for distances over 2 kilometres, no modal transfer if the round trip is for escorting purposes, etc.) and of constraints (individual daily travel-time budgets, the length of each trip, availability of public transport, etc.). An important aspect of the procedure is the fact that it makes total or partial respect for the individual’s daily travel-time budget a primary condition of modal transfer. The constraint imposed by the individual’s daily travel-time acts as a generalised daily travel speed indicator, which plays a role in the assessment of the likelihood of a transfer. Several numerical simulations have been done, using different transport supply scenarios.

In our approach we made the assumption that travel time is the major variable for modal substitution analysis, and other factors, such as comfort or reliability, have been excluded from the substitution analysis. We also assumed that car drivers do not change their everyday patterns of activity and their destinations. Our approach does not, therefore, predict what the modal split might be in other circumstances, as in a conventional demand model, but only the upper limits of the shifts. The result is not a forecast of the achievable level of transfers from the car to alternative modes, but the maximum potential of transfer given the set of rules.

This paper describes our methodology and the major results obtained through numerical simulations based on figures for the Paris and Lyon conurbations. These simulations are based on:

- the most recent household travel survey for each conurbation (the 1991-1992 Paris Region comprehensive travel survey, and the 1994-1995 Lyon Region household travel survey, cf. map 1), which record all trips made in a *typical day* by all individuals over 5 years of age from surveyed households living in these regions. The surveys are based on details of the previous day’s travel collected in face-to-face interviews (for each trip: transport modes, starting point and destination, purpose, departure and arrival time...), as well as the socio-economic characteristics of the household and its members;
- a public transport assignment model whereby trips are assigned to public transport networks on the basis of the shortest time path for each car journey. We used the IMPACT model developed by the RATP (principal Paris public transport operator) for the Paris Region and the TERESE model developed by the Lyon-based SEMALY consulting group for the Lyon Region;
- walking and cycling speeds that provide a potential alternative to trips by private car (or car round trips);

- the current individual cost of mobility. The impacts of modal transfer on daily financial travel budgets are evaluated for each car driver by comparing the marginal cost of daily car use with the cost of public transport use at current prices for the same degree of mobility. For car use, only marginal costs were considered, i.e. fuel and parking costs.

The method is based on repeated iterations of a simulation model that assigns car loops to modes other than the automobile on the basis of a number of improved public transport scenarios. The method makes it possible to simulate the *maximum potential market* for transport modes other than the private car.

2. Methodology

We developed a method based on repeated iterations of a simulation model where "car loops" were assigned to alternative transport modes on the basis of existing public transport supply (called HP-HC 90 for Paris and HP 95 for Lyon – see below) and a number of improved public transport scenarios.

A car loop was defined as the sequence of journeys made between leaving and returning home; an individual might make several car journeys in the same day. Demand was channelled towards individual modes (walking, cycling), public transport routes and a combination of individual and public modes of transport, on the basis of the shortest time path for each trip. *More precisely, each loop in which the first segment was travelled by car* was assigned to another transport mode on the basis of a set of rules and constraints. This system of rules and constraints constitutes the core of the modal transfer procedure, which examines the possibilities of car journey substitution in the context of different public transport scenarios. This method allows us *to identify realistic individual degrees of freedom with regard to existing activity patterns and current daily travel speed, and to evaluate the potential for changes in transport modes (to methods other than the private car) with reference to a transport speed policy.*

Our approach does not take into account the impact on transport demand of any change in supply, in particular additional trips that may be generated by increases in the speed of transport networks.

The following section begins by developing the basic principles of the transfer procedure (2.1) and then goes on to describe the procedure itself (2.2); section 2.3 provides an overview of the current situation in the Paris and Lyon areas.

2.1. Principles of the transfer procedure

This section sets out the main principles and rules applied in the algorithm that deals with the allocation or potential transfer of "private car loops" to other modes.

The four main principles of the algorithm were laid down as early as 1997 at INRETS (Gallez, Orfeuil, 1997). They are successively described below. (More details on methods are given in Massot *et al.* – 2002b).

Car Round Trips

The modal transfer procedure is based on transfer rules that apply to car "loops" as previously defined. This principle is a departure from modal transfer evaluations that consider individual trips (Mackett, Robertson, 2000). It is based on the firmly-based hypothesis (Jones,

1990; Boulahbal, 1995) that an individual's modal choice depends on the activities which he/she plans to carry out when outside the home or during the day. Conversely, we also show that an individual's range of modal choices depends on his/her desired activity schedule. The procedure takes into account the close link between an individual's ability to use a given transport mode and the organisation and geography of the trips he/she makes when outside the home.

More specifically, four rules have been developed on the basis of this principle:

- Any round trip whose first segment is travelled by car is analysed through the transfer procedure. In the vast majority of cases, when the car is chosen for the first segment in a round trip, it is also used for the other segments (in our sample, 93% of the journeys in the Greater Paris Region which were part of round trips whose first segment was by private car, were made entirely by car. The percentage was 95% for the Greater Lyon Region).
- If at least one of the segments in a round trip is judged not to be transferable, this is considered to hold true for all the segments in that round trip.
- All the segments in a round trip are transferred to a single mode.
- Only round trips that take place entirely within the survey perimeter and which are at least partly located within the densely populated zone (see Map 1) are considered. The purpose of this rule is to try to include all car round trips that generate car traffic within the conurbation's densely populated zone.

Compliance with specific car dependence

The second principle takes into account the fact that some activities are highly dependent on car use. Thus, all car "loops" that include activities for which the car is the most suitable mode have been excluded from the procedure: car round trips that include one or more trips for the purpose of "exceptional and weekly shopping" have been excluded. The car has also been considered as essential for any journey that includes more than one escorting function. Lastly, any car journey that includes any night trips has been excluded from the procedure, for reasons of safety and the lack of public transport.

Compliance with daily travel-time budgets

The third principle states that the individual's existing daily travel-time budget (i.e. the daily time devoted to transport) should be respected. Any increase in the daily travel-time budget is analysed and accepted only if it is below a preset threshold that takes into account the existing proportions between travel time and activities (Schäfer, 2000).

The potential increase in the individual's daily travel-time budget was therefore assessed by applying a margin of increase in the travel-time budget for car journeys. The maximum value of the time-budget surplus was set *in advance as a proportion* of the individual's initial travel-time budget and the average travel-time budget of the group to which the traveller and the journey belong (12 groups were defined on the basis of combinations of occupation, gender and activity). The constraints and rules that applied to the travel-time budget were set

using a detailed analysis of the travel patterns of residents in the area (Massot *et al.*, 2002a; Bonnel *et al.*, 2002).

- Any individual whose initial travel-time budget was greater than 300 minutes was excluded from the transfer procedure, on the self-evident grounds that this travel-time budget was too high.
- When an individual's initial travel-time budget was twice his or her group's average travel-time budget, transfer was only possible if the travel-time remained constant or fell. This level of twice the average was considered the maximum value for the travel-time budget, above which the individual's travel-time budget could not increase.

This rule places the travel-time parameter at the heart of the methodology, making speed a key part of the system. Those variables constitute a way to measure how a scenario behaves and how it affects individuals, especially within the context of a strategy for reducing car use.

Modal segmentation of the car journey market

The procedure is also able to reflect competition between modes in terms of distance travelled and speed. The transfer of a car "loop" to one of the three alternative modes (walking, cycling, public transport) depended on the total distance of travel. Several distance classes were specified, based on an analysis of all the journeys whose principal mode was walking or the bicycle.

- Transfer to walking was tested for car journeys of 2 km or less. The baseline walking speed was 3.5 kph.
- Transfer to cycling was tested for car journeys of less than 11 km (depending on the individual's age and the purpose of the trip). The associated speeds were set between 5 and 11 kph.
- Transfer to public transport (PT) was tested for other distances on a time basis. The public transport time for all segments within a car journey was computed using an assignment model (IMPACT and TERESE). The model gave the shortest time path assignment. The calculation was performed for the baseline network and for the different network designs defined in the improved public transport scenario.

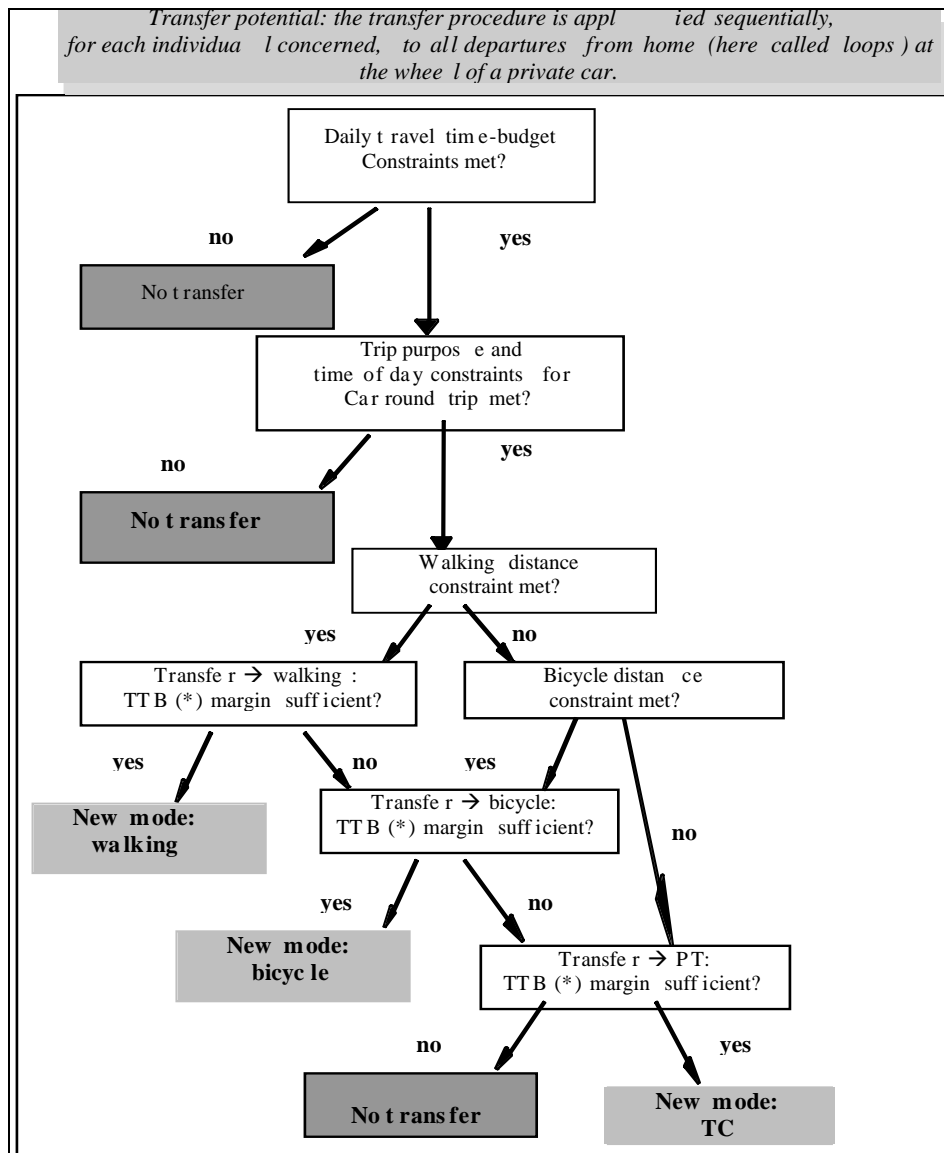
2.2. The procedure

On the basis of the above set of rules, the transfer procedure was applied sequentially to all car journeys made by each individual (Figure 1). Priority was given to individual travel-time budget constraints; transfers of an individual's round trip or journey were effected under the following conditions:

- **IF** the travel-time budget constraints or one of the trip's purpose and time of day constraints for the car journey were not satisfied, **THEN** the individual's car journey was not transferred;
- **OTHERWISE**, the car journey was transferred according to the following procedure:
The first transfer mode that was tested (walking, cycling or public transport, in that order) depended on the total distance covered in the car journey:
 - o **IF** the increase in the travel-time budget after transfer was below the threshold set in advance **THEN** the procedure was successful, transfer was possible and the travel-time budget was changed accordingly.

- o **IF** the increase in the travel-time budget exceeded the threshold, transfer to a faster mode was tested (cycling where the transfer to walking was tested first, public transport if the transfer to cycling was tested first).
- o **IF** none of the modes was able to meet the travel-time budget conditions **THEN** the transfer failed for all segments of the car journey.

Figure 1: Simplified modal transfer procedure for individual car round trip



Source: INRETS (Massot et al, 2002a)

2.3. Application to the more densely populated areas

The transfer procedure has been applied to the most recent household travel surveys in the two conurbations studied.

Our analysis was only based on car round trips realised in the more densely populated area of the Paris and Lyon conurbations, where there is real competition between transport modes. For example, the total daily trips in the Paris study zone, which is not far from the heart of Paris, accounted for 66% of all sample journeys (i.e. 21 million out of 33 million daily trips) and for 75% of total daily traffic (in kilometres) (table 2). In this densely populated area, "alternative" transport modes (walking, cycling and public transport) represent the dominant modal share, and public transport is the most used travel mode in terms of daily traffic (51%).

In the Paris conurbation, therefore, only one car trip in six is eligible for evaluation by the transfer procedure. However, the proportion is twice as high in Lyon, because the car represents a much larger share of the market (table 2 and 3). Again, slightly more than one person in six in the Paris region made car trips included in the transferable potential, while the proportion was twice as high in the Lyon conurbation. Finally, the average distance covered in car trips was more than 30 km in the Paris conurbation and a little over 10 km in the Lyon conurbation. The size of the conurbation seems to play a particularly important role.

Table 3 shows the extent of car traffic eligible for evaluation by the transfer procedure. The survey perimeter for each conurbation is given in Map 1.

Table 2: Modal share in the two more densely populated areas
(Baseline state)

Transport Mode	More densely populated area of Paris conurbation		Greater Lyon	
	Trips	Traffic (km)	Trips	Traffic (km)
Walking	35.5%	3.6%	31.1%	8.6%
Cycling	0.4%	0.2%	0.6%	0.4%
Motorcycling	1.0%	1.1%	0.6%	0.8%
Private Car Passenger	7.8%	7.5%	12.1%	14.4%
Private Car Driver	28.3%	35.8%	42.0%	58.2%
Taxi	0.4%	0.4%		
Public transport	26.3%	50.7%	13.3%	17.0%
NR	0.4%	0.7%	0.4%	0.5%
Total	100%	100%	100%	100%

Source: INRETS, based on EGT (DREIF) 91-92;

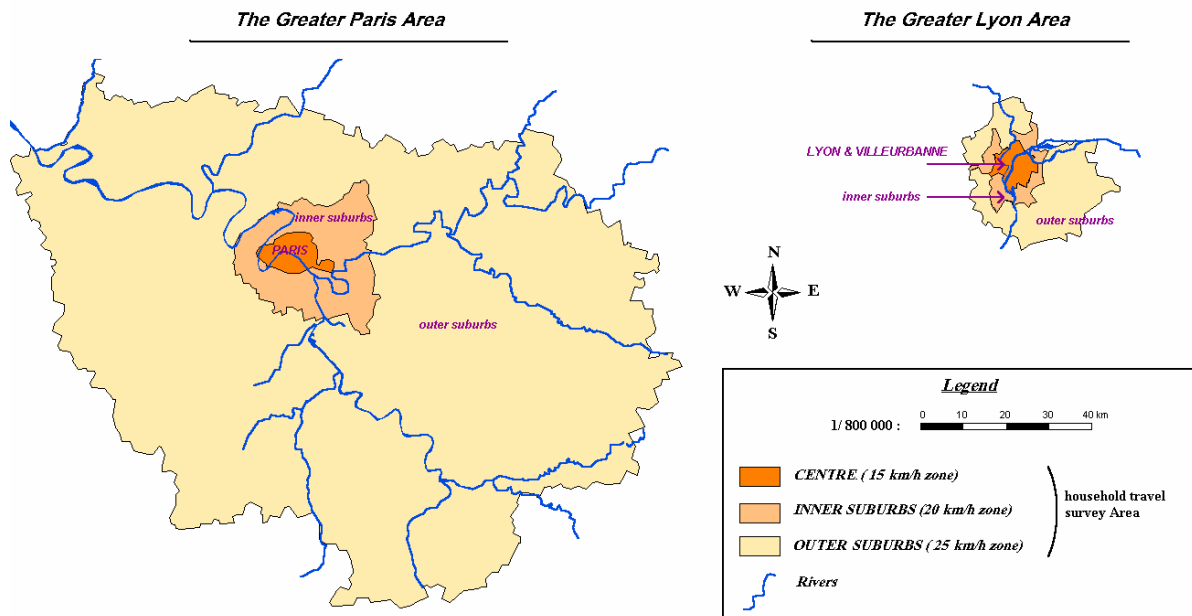
LET, based on EM Lyon (SYTRAL) 1994-1995

Table 3: Extent of car traffic eligible for evaluation by the transfer procedure in densely populated areas

	Number of Trips (In 000s)	Number of car Trips eligible for evaluation by transfer procedure (In 000s)	Number of trips contained in car "loops" eligible for evaluation by the transfer procedure (In 000s)	Number of persons making car "loops" eligible for evaluation by the transfer procedure (In 000s)	Number of driver car-kilometres in car "loops" eligible for evaluation by the transfer procedure (In 000s)
Greater Paris	12,983	2173	6402	1701	65,896
Greater Lyon	1802	672	1866	436	7160

Source: INRETS, based on EGT (DREIF) 91-92;
LET, based on EM Lyon (SYTRAL) 1994-1995

Map 1: Study zones



3. Potential for car traffic reduction

3.1. The issue of car speed in car use regulation

On the basis of car use observed in 1991 in the densest part of Ile-de-France, of the baseline public transport level (HP-HC 1990) and of the transfer procedure criteria, 9% of car drivers were potentially able to maintain their everyday mobility patterns with modes other than car travel without increasing their daily travel-time budget. These car drivers were therefore deemed to be “irrational” in terms of modal performance speed. By contrast, 91% of drivers, representing 93% of car trips and 95% of daily car traffic (car kilometres) were assessed as unsuitable for modal transfer without an increase in their daily travel-time budget. The method therefore confirms that the great majority of car users are effectively employing the fastest method of travel.

If the same activity patterns are maintained (our assumption), we can therefore conclude that reducing “irrational” car usage can contribute only marginally to a large-scale reduction in car usage.

If we analyse the social profile and mobility patterns of the car users not deemed suitable for modal transfer, we find a large proportion of working people with a high level of mobility: 87% are working people who make 4.5 trips a day at an average speed of 19 kph. These car users spend two hours a day in their car for a mean daily travel distance of 37 kilometres. These figures are higher than those for the total population in this area (51% of working people, 22 kilometres a day at 16 kph for a daily travel-time budget of 82 minutes and a level of mobility of 3.5 trips a day). In the Paris conurbation, *we can conclude that the great majority of car users have constructed their daily activity patterns around car speed performance.*

The challenge that car speed performance presents for car use regulation can thus be considered as very high. In fact, further simulations show that it is even higher.

In these simulations, based on the current level of public transport supply (HP-HC 90), it is assumed that car drivers are prepared to accept an increase in their travel-time budget (~ a reduction in their general travel speed over the day). Simulations were performed using 10% increments over their current travel-time budget, from 10% up to 100% (which is highly speculative).

If the same individual activity patterns are retained and if no increase in car traffic is induced through modal transfer, doubling the individual travel-time budget could lead to a **37% reduction in car trips**. This implies that **63% of car trips would maintain the link with car speed performance** (they accounted for 74% of previous car traffic – see last line, table 4). A more realistic 25% growth in travel-time budget leads to a transfer of 16% of car trips to alternative modes, which means that **84% of car trips and 91% of car traffic might maintain the link with the car speed performance criterion** (see line 3, table 4).

Table 4: Potential car speed dependence based on the hypothesis of an incremental increase in individual daily travel-time budget.

% increase in daily travel-time budget	More densely populated area of Paris		Greater Lyon	
	% car loops remaining dependent on car speed performance	% car-km remaining dependent on car speed performance	% car loops remaining dependent on car speed performance	% car-km remaining dependent on car speed performance
0%	93%	95%	86%	94%
10%	90%	94%	82%	91%
25%	84%	91%	77%	88%
30%	82%	90%	76%	87%
40%	78%	88%	73%	85%
50%	75%	85%	72%	85%
75%	72%	79%	72%	84%
100%	63%	74%	71%	84%

Source: INRETS, based on EGT (DREIF) 91-92;
LET, based on EM Lyon (SYTRAL) 1994-1995

What general conclusions can be drawn from these simulations?

We compared these simulations with those for another French city, Lyon (Massot, Armoogum, Bonnel, Caubel, 2002b). Here, the percentage of drivers who could not have followed their daily activity patterns otherwise than by car without altering their travel-time-budget, is lower than that in the densely populated part of the Greater Paris Area (82%). It is thus apparent that in more relaxed constraints for car use (congestion, trip time irregularities, parking problems, etc. are greater in Paris than in Lyon.), car use behaviours are less “rational” in terms of time spent. In Lyon’s more relaxed car conditions, we observe, as Kaufmann (2002) points out, that “competitive travel times are a necessary but not a sufficient condition for public transport use”, even if this travel mode is the fastest.

Therefore the percentage of “irrational drivers” was greater in Lyon than in the densely populated part of the Paris Area (16% versus 9%, table 4). But the traffic involved in such “irrational” car use is comparable to that obtained for the Paris conurbation (6% of car kilometres in Greater Lyon). The level of mobility of Lyon car drivers is no less intensive than those of Paris, but their car trips are shorter and slower. Because of that, the modal split of potentially transferable trips is structured differently.

In the more densely populated area of Paris, public transport would absorb 66% of potentially transferable car trips and 95% of the vehicle-kilometres travelled while making them. Walking, which has been assumed potentially to replace car trips of less than 2 kilometres, only absorbs 8% of potentially transferable trips, while the bicycle, which is assumed to replace round trips of less than 8 kilometres, absorbs 26%. These two individual modes are only responsible for 5% of the reduction in automobile traffic (in terms of vehicle-

kilometres). Apparently, in the densely populated Greater Paris Area, although there is the potential for solving the problem of modal transfers by transferring short trips to foot or bicycle travel, which are effective substitution modes, such a shift produces relatively marginal reductions in automobile traffic.

In the more densely populated area of Lyon, although walking is no more prevalent than in Paris, the bicycle is potentially the most significant mode involved, accounting for 64% of potentially transferable car trips and 41% of car traffic. Public transport substitution accounts for only 28% of potentially transferable car trips but 57% of traffic. Even if public transport were the primary mode in traffic terms, this result shows that in the Lyon region, modal transfers involved a different scale of strategies than in the more densely populated area of Paris.

If it is assumed, as for the Paris case study, that car drivers were prepared to accept an increase in their travel-time budget, the issue of car speed does not seem to be so important in the Lyon case-study as in Paris. In Lyon, the increase in the travel time-budget was observed to have a greater impact on reducing dependence on car speed, provided that the simulated increase in car users' daily time-budget remained below 25%. Above that level of increase, the correlation between car traffic dependence and car speed is quite constant, and higher than for the Paris case-study (table 4). When all the shorter and slower car trips, which are more numerous in Lyon than in Paris, are re-assigned to another modal alternative, the potential for car journey transfer depends on the performance of the public transport system (in potential departure points/destinations and speed). The Parisian PT network performs better than its Lyon equivalent: this may explain why car traffic dependence decreases in line with the increase in the travel-time budget in Paris and not in Lyon.

3.2. Potential car use reduction assuming improvements in public transport

The transfer procedure was first applied on the basis of public transport supply as it stood at the dates when the Paris and Lyon surveys were each conducted. Having analysed the characteristics of the transferred and non-transferred round trips, we proposed several scenarios involving improved public transport supply. The procedure used to construct these scenarios entailed successive improvements to supply.

As the baseline levels of public transport supply are very different in the two conurbations (Table 5), different scenarios had to be established for each context. The more detailed nature of the data on the Paris region enabled us to construct 7 supply scenarios (Massot *et al.*, 2000). Only 5 scenarios were specified for Lyon (Bonnell *et al.*, 2002). In this paper, we will discuss only the scenarios that present the most contrast:

- For the Paris conurbation:

- HP-HC 90, which corresponds to the network as it stood in 1990 shortly before the Comprehensive Transport Survey was conducted in the Paris region. This is therefore the baseline network.
- HP99, which corresponds to the network as it stood in 1999, with peak hour frequencies extended in the simulation to off-peak periods and the implementation of the projected Mobilien plan (creation of 60 exclusive bus lane routes in Paris and the suburbs leading to speeds of 15 kph in the centre, 20 kph in the inner suburbs and 25 kph in the outer suburbs, RATP 2000).

- HP2010 + 15,20,25, which is the same as the previous network, but with increased supply in the outer suburbs through the creation of intersuburban routes and increased rail supply, in line with the Masterplan, which is based on the 12th and 13th State-Region plan contract. It is also accompanied by a restructuring of the bus network to match rail supply. Finally, this supply includes exclusive new bus lanes throughout the roads network, leading to standard speeds of 15 kph in the centre, 20 kph in the inner suburbs and 25 kph in the outer suburbs.
- **For the Lyon conurbation:**
 - HP95, which corresponds to the network as it stood in 1995, the date when the Household Travel Survey for the Lyon conurbation was conducted. This is therefore the baseline network. However, as the network is only encoded for the peak period, this scenario implicitly entails peak hour frequencies being applied to off-peak periods. It therefore already represents a considerable improvement on the real situation in 1995;
 - HP2010 PDU, which corresponds to the scenario described in the Plan de Déplacements Urbains (Urban Travel Plan) for the conurbation in the year 2010 (SYTRAL, 1997). In particular, this plan envisaged the creation of 10 high-capacity routes in addition to the 4 existing metro lines;
 - HP2010+ rail +15,20,25. This is the previous scenario with the addition of a general growth in rail services (based on the existing network, which is little used at the present time). As in the case of the Paris conurbation, we have also included the creation of exclusive bus lanes, which lead to standard speeds of of 15 kph in the centre, 20 kph in the inner suburbs and 25 kph in the outer suburbs.

Table 5 shows the scale of the increase in the public transport supply. In comparison with the baseline scenarios, the most ambitious simulations produce a 44% increase in seat kilometres for Paris and 92% for Lyon. The second figure represents a doubling of supply and is more than twice the increase in capacity obtained for the Paris conurbation. So the simulated changes in the public transport supply are not marginal, despite the fact that in the most ambitious network in Lyon, supply in terms of seat kilometres per resident is at the same level as it was in Paris in 1990.

Table 5: Supply indicators for the public transport scenarios

	Greater Paris area			Greater Lyon area		
	HP-HC 90	HP99	HP2010 + 15,20,25	HP95	HP2010 PDU	HP2010+ rail + 15,20,25
Seat kilometres per year (billion)	106.7	143.4	154.2	7.2	12.6	13.9
Population of survey zone (thousand)	10,464 (Paris region, 1990)			1195 (in 1995)		
Seat kilometres per person per year	10,023	13,704	14,736	6085	10,554	11,653

Sources: INRETS, based on IMPACT models (RATP)
LET, based on TERESE models (SEMALY)

We can observe (table 6) the potential effect of these public transport supply improvements for both the study areas, assuming present day car usage and daily travel-time budgets.

The most ambitious supply scenarios place the rail network at the centre of the transport system. However, the results show a very small increase in potentially transferable car trips and only a very slight drop in car dependence. In the Paris study areas, the most ambitious PT improvement scenario (HP2010 + 15,20,25) might produce a **9% reduction in car trips**, which means that **91% of car trips would continue to be linked with car speed**; they account for 93% of the previous car traffic (table 4). This impact is real albeit limited, in terms both of car trips and car-kilometres relative to the baseline situation, where **93% of car tours maintained the link with car speed**.

The figures obtained for the Lyon case study are also disappointing: in the Lyon study areas, even with the most ambitious transport supply scenario (HP2010+ rail +15,20,25) **89% of car traffic retained the link with car speed** (table 6).

Our analysis explains this disappointing result as follows for both cases: the simulated public transport supply pattern remained essentially radial, and therefore only able to replace equivalent car trips over long radial distances. Its spatial layout was too inflexible to assimilate car trips in the inner suburbs, which were statistically the most numerous. This observation should not, however, lead us to conclude that existing plans for public transport supply changes are of no importance for the Greater Paris and Lyon areas. Such plans are based partly on forecast population increases in the relevant areas, which is a factor not taken into account in the simulations. We show that they may only have a limited effect on the additional modal share that the car acquired in the 90s, i.e. on the competition for speed between the car and public transport.

While the estimated impact of transport supply on changes in present-day car usage in densely populated zones was real, albeit limited, the impact of public transport supply *could be increased* by any accompanying strategy that aims to promote "transfers" to other modes, i.e. any strategy that might reduce car speed. In fact, it was observed (table 7) that a 25%-30% increase in car drivers' daily travel-time budget (reasonable hypothesis) could leverage the impact of public transport supply improvement on car speed dependence and increase the potential role of alternatives modes. This confirms the hypothesis, widely accepted in

professional circles, that future changes can only come about through a synergy between “combined” measures. However, it could also be observed that, of these two measures, the greatest impact on car usage regulation would come from enforced reductions in car speed: a 25% or 30% increase in the individual daily travel time-budget (with baseline PT supply levels) had a greater impact than improving transport supply, for the same daily travel-time budget (Table 4). If the objective is to reduce car use, the first step is to lengthen daily car trips, and the second to develop accompanying strategies to amplify modal transfer.

Table 6: Potential correlation between car use and car speed assuming an increasing public transport supply with a **constant daily travel-time budget**

More densely populated area of Paris	Public Transport Scenarios		
% Traffic dependent on "car speed"	(HP-HC 90) Baseline	(HP, 99)	(HP 2010) +15/20/25
Car Trips	93%	92%	91%
Car –km	95%	94%	93%
Greater Lyon	Public Transport Scenarios		
% Traffic dependent on "car speed"	HP95 Baseline	HP2010 PDU	HP2010+ fer + 15-20-25
Car Trips	87%	84%	83%
Car –km	94%	91%	89%

Source: INRETS, based on EGT (DREIF) 91-92;

LET, based on EM Lyon (SYTRAL) 1994-1995

Table 7: Potential correlation between car use and car speed assuming an increasing public transport supply (as above) **and an increase in the daily travel-time budget**

More densely populated area of Paris: 25% increase in travel-time budget	Public Transport Scenarios		
% Traffic dependent on "car speed"	(HP-HC 90) Baseline	(HP, 99)	(HP 2010) +15/20/25
Car Trips	86%	82%	82%
Car –km	91%	87%	87%
Greater Lyon: 30% increase in travel-time budget	Public Transport Scenarios		
% Traffic dependent on "car speed"	HP95 Baseline	HP2010 PDU	HP2010+ fer + 15-20-25
Car Trips	78%	74%	72%
Car –km	87%	81%	77%

Source: INRETS, based on EGT (DREIF) 91-92;

LET, based on EM Lyon (SYTRAL) 1994-1995

4. Car use regulation and acceptability of travel-time constraints

In order to assess whether transferred car trips might constitute a potential market for alternative modes, we tried to evaluate the impact of transfers on car users.

We analysed two simulations: the first is based on the baseline situation (unchanged individual travel-time budget and PT supply) ; the second is based on a 25% or 30% increase in the daily travel-time budget and an unchanged PT supply.

The analysis of the first simulation demonstrated that strategies that entailed the transfer of some or all individual daily car trips would generate travel-time budget gains for all the car drivers in both the Paris and Lyon cases. The average reduction in time spent in daily travel is significant: 20 minutes for car drivers in Paris and 18 minutes for car drivers in Lyon (respectively a 15 and 20% reduction in daily travel time).

The financial impact on the daily travel-budget is quite different in the Lyon and Paris cases. For 97% of the car drivers in the Paris area, the transfer strategy would result in significant average daily savings of more than 3 Euros, i.e. a 68% reduction in their daily travel budget. In the Lyon case study, the average monetary saving is smaller than in the Paris case (0.23 Euros or 15%), as is the number of financial winners (76%). This difference may be explained both by the higher cost of car use in terms of parking expenditure and the much lower cost of public transport in Paris as compared with Lyon. In Lyon there is very little difference between the unit cost of using the two motorised modes: this could also explain why more people opt to drive in Lyon than in Paris.

In the first simulation, where the winners in time and money would be numerous and the savings significant, it is possible that a modal transfer might be viable for some car drivers. However, as we have seen, the impact in terms of car traffic reduction would be limited (5% - 6%).

The second scenario, based on a 25% increase in the travel-time budget, entailed a potential 9% reduction in car-kilometres for 19% of car drivers (326,000) in Paris. Although this scenario did not affect **91%** of existing car traffic, the car's share in total trips would fall **from 36%** (baseline case) **to 31%**, a potentially significant drop. Public transport would absorb 80% of the transfers. As regard the impact of transfers, the analysis demonstrated that strategies entailing a transfer would result in financial and time gains for 39% of cars drivers involved. Only 9% of drivers would lose time and money and the majority were in a position to balance monetary gains against time losses. We feel that these pieces of data on individual impacts show that the sacrifice required of many drivers is limited and probably acceptable, in view of the fact that the monetary gains were substantial and the time losses negligible; in straightforward terms, a policy that reduces car use would not penalise these drivers, as long as public transport pricing remains unchanged. In addition, car traffic reductions would be less marginal than in the previous example. The analysis of other scenarios, where public transport supply is reinforced, do not radically alter the diagnosis; we observe that improvements in supply do not affect the increase in travel time-budgets for car drivers making a modal transfer (table 8).

Table 8: Potential impact of modal transfer on daily travel-time and monetary budgets
Simulations based on an increase in travel-time budget with constant public transport supply

Paris case study		Time-budget (Minutes)		Monetary Budget (Euros 95)	
Car drivers transferring and:	Car drivers concerned	Before Transfer*	After Transfer	Before Transfer*	After Transfer
Saving time and money	39%	135	115	5,26	1,54
Saving time and losing money	5%	83	70	0,61	0,85
Losing time and saving money	47%	97	109	3,70	1,63
Losing time and money	9%	89	102	1,40	1,74
Lyon case study		Time-budget		Monetary Budget	
Car drivers transferring and:	Car drivers concerned	Before Transfer*	After Transfer	Before Transfer*	After Transfer
Saving time and money	40%	80	62	1,40	0,73
Saving time and losing money	11%	116	92	1,34	2,48
Losing time and saving money	32%	71	80	1,95	1,34
Losing time and money	17%	80	93	1,46	2,36

Paris case study

Relative change	Time-budget	Monetary Budget
Saving time and money	-15%	-70%
Saving time and losing money	-16%	41%
Losing time and saving money	12%	-56%
Losing time and money	15%	24%

Lyon case study

Relative change	Time-budget	Monetary Budget
Saving time and money	-22%	-47%
Saving time and losing money	-21%	85%
Losing time and saving money	13%	-32%
Losing time and money	17%	60%

***Before transfer = in the baseline situation**

Source: INRETS, based on EGT (DREIF) 91-92;

LET, based on EM Lyon (SYTRAL) 1994-1995

The simulation based on a 30% increase in the travel-time budget of Lyon car drivers differs from Paris as regards the distribution of financial winners and losers, because of the higher cost of public transport in Lyon. The potential reduction in car traffic associated with modal transfer is a little greater (11%), but the transfer is perhaps less affordable unless the cost of car use increases.

The few figures we have given above, which of course only show maximum potential changes, measure the “realm of the possible”. This “realm of the possible” also reduces

energy consumption and pollution. It does, however, pose a problem of social acceptability, insofar as the sacrifice in terms of transferred vehicle-kilometres is distributed among a small fraction of the drivers involved (around 70% of car traffic reduction from 50% of car drivers). Also, for employees, the average time sacrifice required is greater than for senior and middle managers; in addition, the big winners are over-represented in the population of central Paris, while the big losers are over-represented in the inner suburbs where the potential for adopting effective alternative modes is the lowest (not the case for Lyon).

5. Conclusion

The private car currently dominates travel in large metropolitan areas and its use is on the increase, in spite of the fact that public opinion is generally in favour of better public transport and political approaches that reflect this preference. Furthermore, the available projections and an analysis of the effect of conventional policies (restricted parking, better public transport, economic measures (congestion charges) or taxation (Internal Tax on Oil Products – TIPP)) indicate that although such policies are able to exert some control, that control is limited.

Against this background, this research explored the upper limits for modal transfer of car traffic to “alternative modes” (public transport, cycling, walking). The evaluation of the possible extent of modal shifts from car use to “alternative modes” is based on a simulation approach with explicit rules and assumptions. This system of rules and constraints constitutes the core of the modal transfer procedure, which examines the possibilities of mode substitution in the context of present-day or future transport supply and allows us to identify realistic margins for manoeuvre with regard to individual travel.

In our approach, we supposed that travel time is the major variable for modal substitution analysis and that car drivers do not change their day-to-day activity patterns and destinations in response to changes in transport supply. Unlike a conventional demand model, therefore, our approach cannot predict what might be the modal split in other circumstances, but only the upper limits of the shifts given the set of rules.

The results of our analysis suggest that only a few car drivers would save time by using other modes if the same activity patterns are retained (our assumption). The fact that the great majority of car travellers opt for the faster travel mode is confirmed by the method used. For the great majority of car drivers in this area, a reduction in speed would be synonymous with a reduction in mobility. As Goodwin (2001) states, we should make a distinction between car-dependent people and car-dependent trips. In the very densely populated section of Paris, where public transport supply is excellent, current car users are mainly car-dependent people, and reducing the attractiveness of the car (especially as regards speed and flexibility) is a difficult challenge for any transport policy.

Can we counter the speed addicts who are today’s car users? Our initial results suggest, as has been argued elsewhere, that this is a difficult but not impossible goal. It emerges from the simulations that the potential changes are greater than demand models suggest (Morellet, 2002 – RATP 1999), but also that car traffic reduction could not exceed a few percentage points (around 10 points) without seriously altering activity patterns and travel time for the great majority of drivers.

Our analysis of the potential responses of car users to modal transfer shows that it is possible to devise traffic policies that reduce car traffic by a few percentage points (10) without major disruption to existing activity patterns and travel time for the majority of

drivers. Reducing car speed (by reducing road or parking capacity) might be a more appropriate policy. It is more efficient than any increase in public transport supply. Improvements in public transport supply alone, however great, cannot limit the dominance of the car: to be effective, improvements in public transport need to be accompanied by reductions in car speeds, if the cost of individual mobility remains unchanged. However, such changes could skew the burden unfairly in favour of management and middle-management grades. They are likely to generate a debate on the social acceptability of policies to reduce car use and the measures necessary to make the policies more tolerable or more “politically” acceptable.

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BIONOTES :

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